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Using leverages for objective analysis of PSMSL tide gauges in Arctic Ocean sea level reconstruction

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Introduction

For reconstructing historical sea levels in the Arctic area, lack of data presents a major challenge. We attempt to adapt the model by Church et al. (2004), examining inclusion criteria for tide gauges in the area.

The reconstruction model is based upon spatial, stationary patterns of variability extracted from a calibration period, usually satellite data. These patterns are determined as empirical orthogonal functions (EOFs). The model determines, for each point in time, an appropriately weighted sum of these, constrained locally by tide gauge records and regularized per Kaplan et al. (1997).

The *leverage* of each tide gauge is a statistical measure of its influence on the result. This way, we can readily identify possible outliers among the tide gauge records in a procedural, objective way.

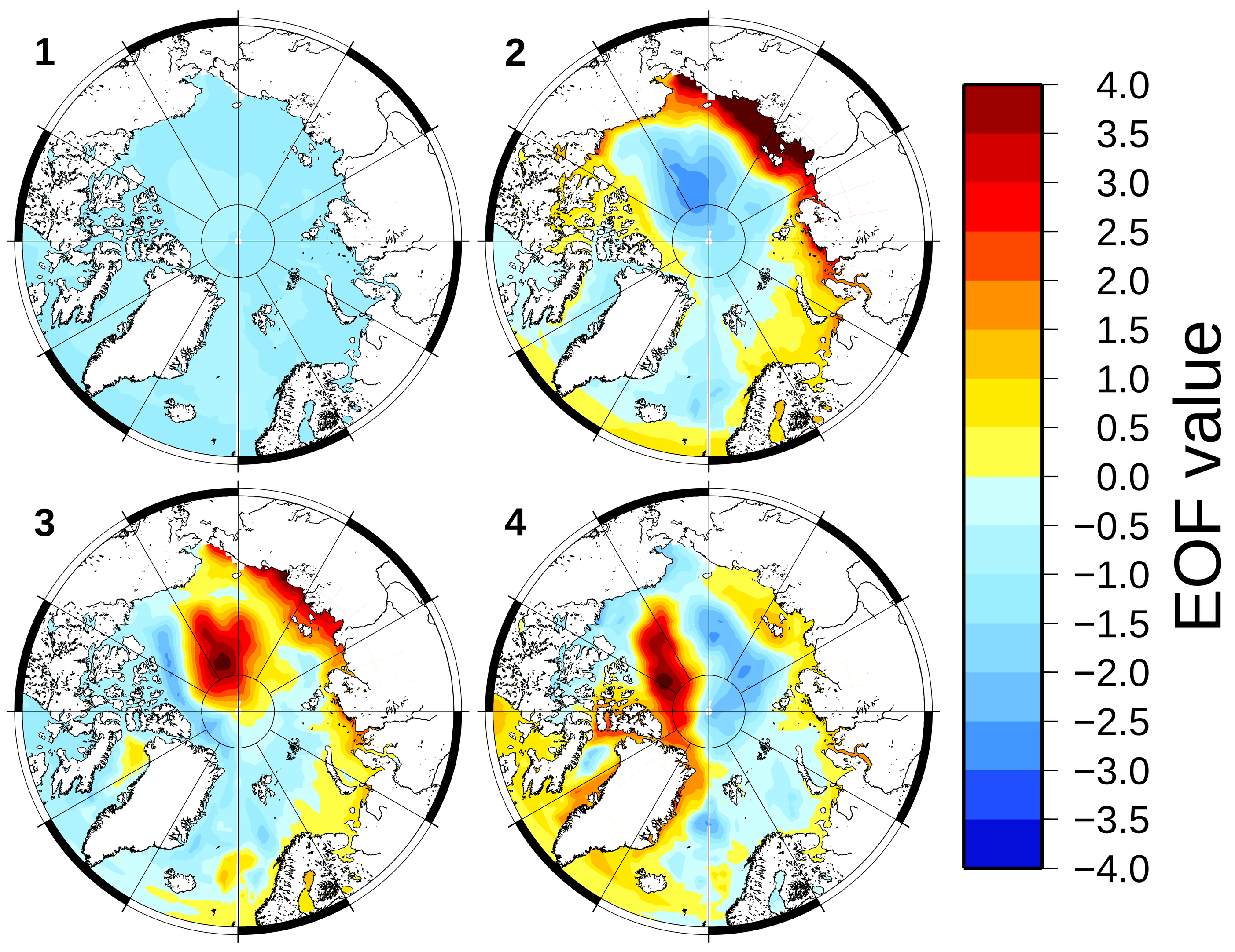
Data

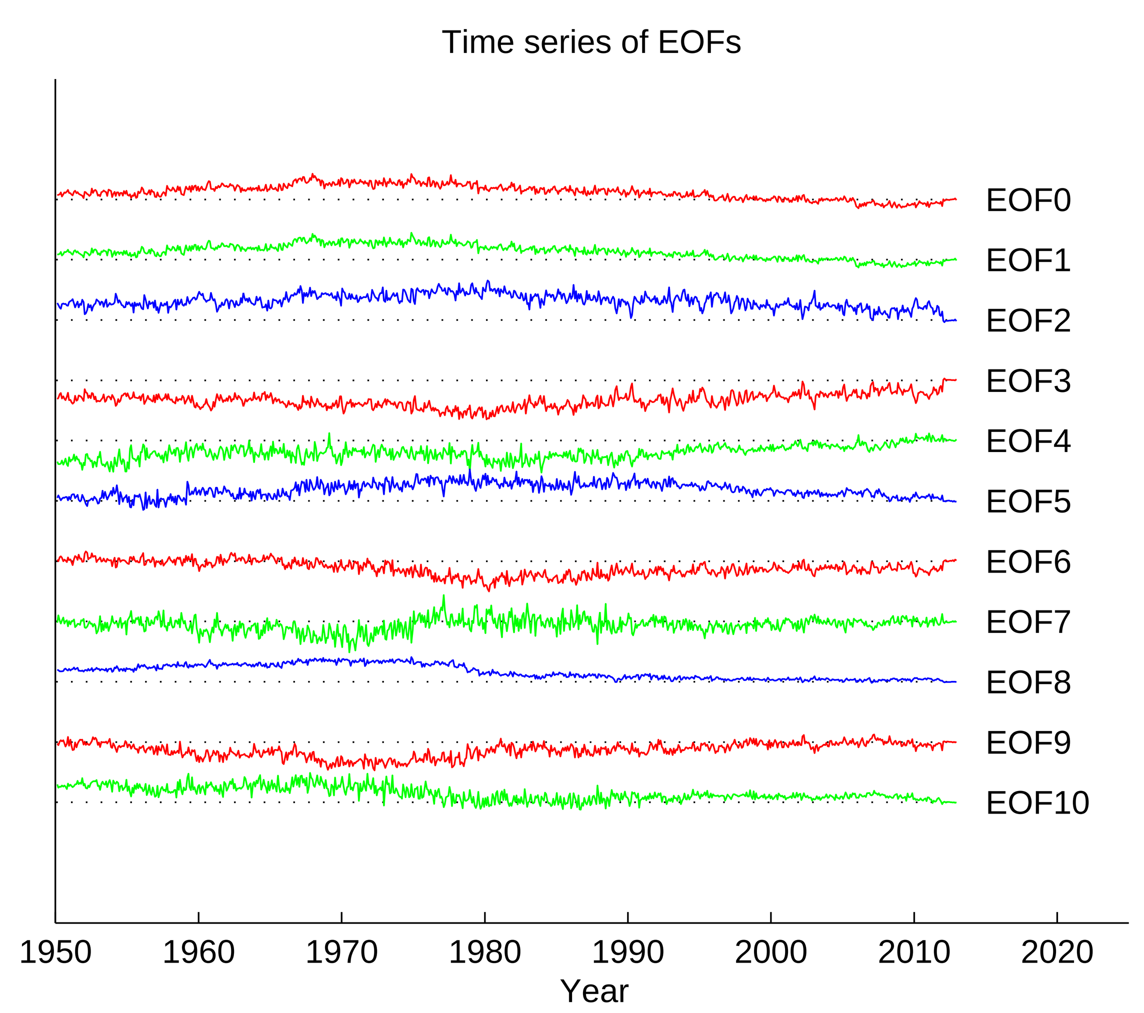
We use monthly PSMSL tide gauge data (RLR only) above approx. 60°N, allowing only records from stations with more than 5 years of data. We use the first differences of the time series to work around vertical datum considerations, then integrate the results, as in Church et al. (2004). GIA correction has been applied to the tide gauges, using the Peltier ICE-5G model (Peltier, 2004).

For this preliminary analysis, the EOFs have been extracted from the Drakkar ocean model (1949–2008).

EOFs

The reconstruction model incorporates a spatially uniform pattern (known as an "EOF0"), in addition to the leading ten EOFs. The first four of these are shown below.





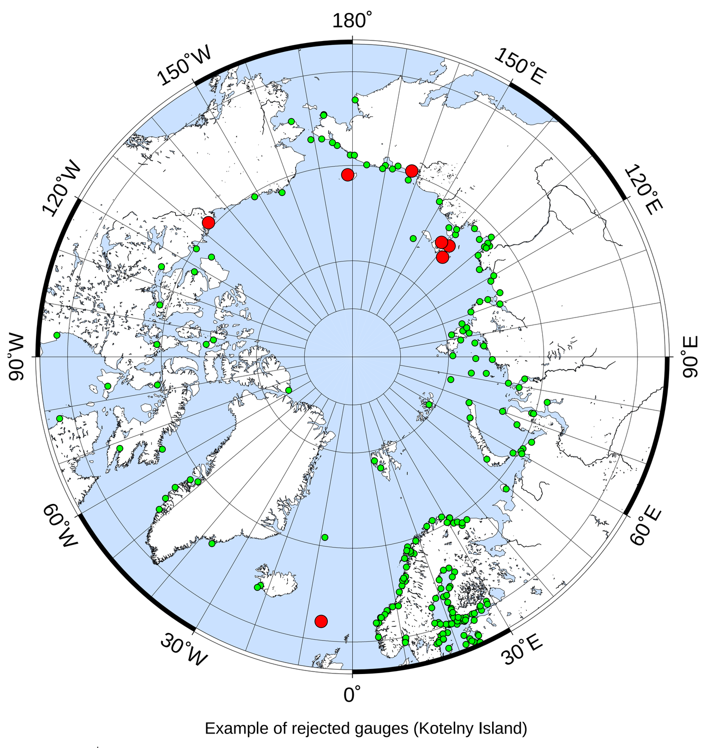
EOF1 is fairly close to uniform and may capture a large amount of overall trend. It is by far the dominant mode in the Drakkar data, explaining almost 90% of the variance.

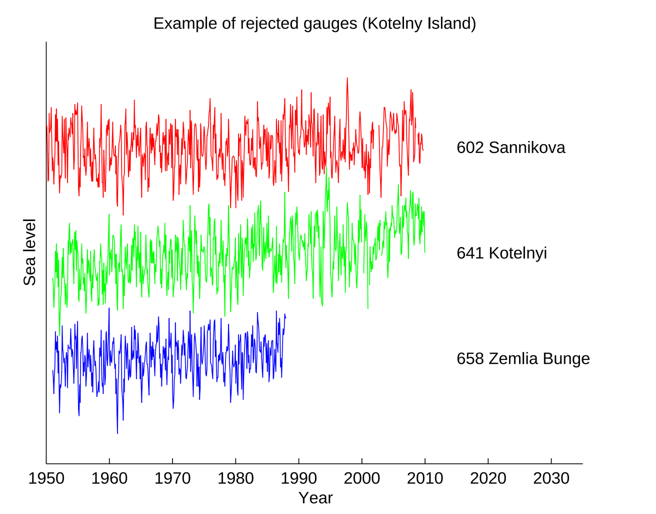
High-leverage gauges

In least-squares regression, the leverage of each observation is given by the diagonal elements of the "hat matrix" that relates the response variable y (in this case, tide gauge records) to its estimate, $\hat{y}$. See e.g. Nielsen, 2013.

The map shows all tide gauges included in the reconstruction (green) and those rejected due to high leverage (red). Rejection criterion here is three times the mean gauge leverage.

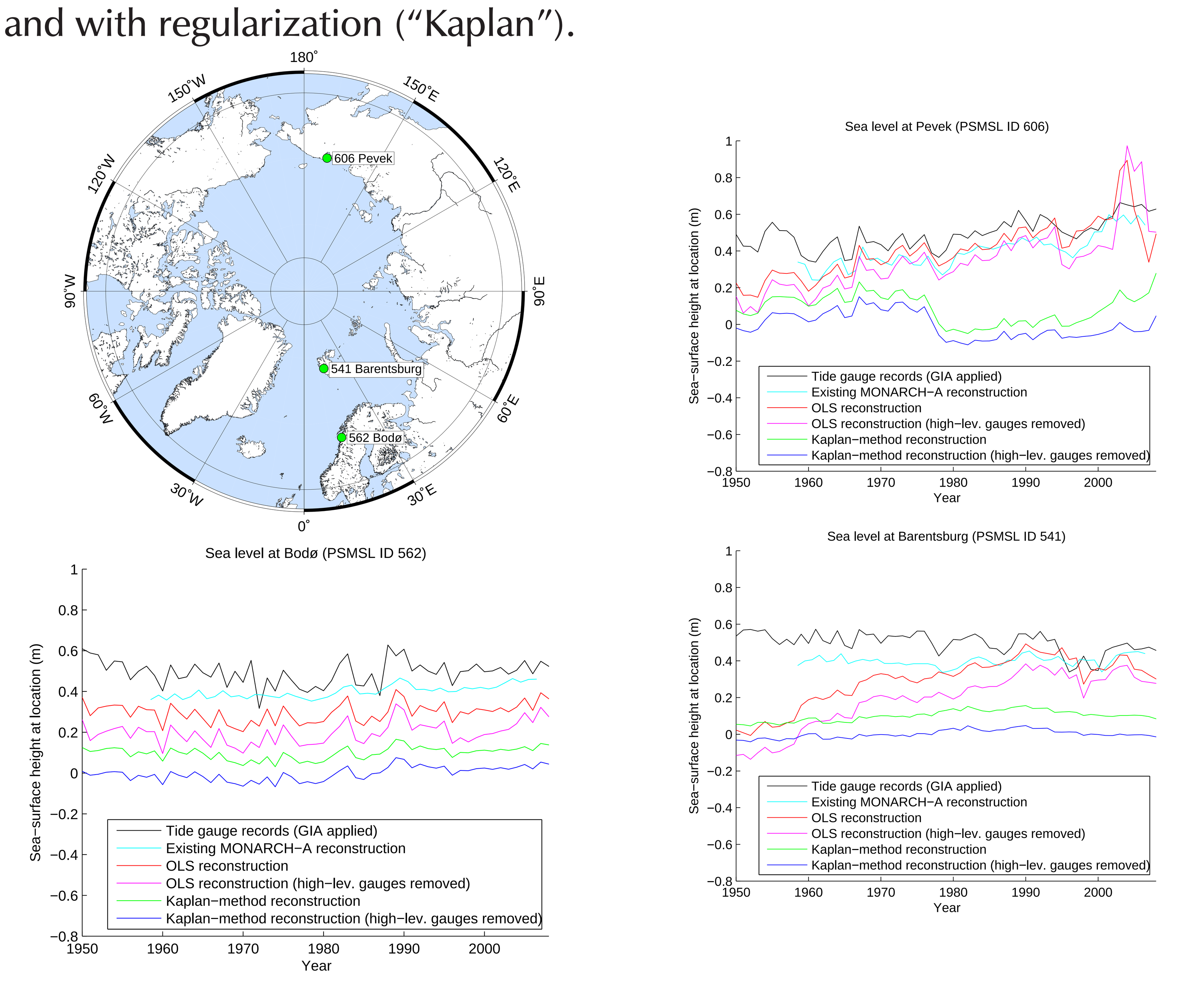
The plot shows an example of rejected gauges, the three on Kotelny Island (75°N, 140°E). These gauges may simply not be sufficiently represented within the appropriate EOFs.





Local reconstruction ability

To assess the validity of the results, the reconstructed sea-level time series in selected points have been plotted and compared with actual tide gauge data and the existing MONARCH-A reconstruction (by Henry et al.). The model has been applied both without regularization ("OLS") and with regularization ("Kaplan").



The unregularized reconstruction seems more prone to developing nonexistent trends in the time series, and not very appropriate for this purpose. Removing a handful of gauges of high leverage seems to dampen the oscillations near the coast considerably, while keeping almost the same behaviour in open ocean.

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